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Nagasaki

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(54) **PRINTED CIRCUIT BOARD EQUIPPED WITH PIEZOELECTRIC ELEMENT**

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H01L 41/107 (2006.01)

(52) **U.S. Cl.** **361/767**; 361/760; 361/764; 361/783; 361/794; 323/222; 323/355; 363/21.13; 363/61; 310/316.01; 310/348

(58) **Field of Classification Search** 361/760-767, 361/783-784, 794, 807-810, 836; 310/344, 310/316.01, 318, 319, 348; 323/222, 268, 323/271, 282, 285, 288, 355; 363/21.13, 363/59, 60, 61, 40, 124, 16, 97, 131; 174/254-264
See application file for complete search history.

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(57) **ABSTRACT**

An electronic apparatus includes, for example, a circuit board with an electronic component and a piezoelectric element, a reference potential pattern that gives a reference potential to at least one of the electronic component and the piezoelectric element, and a solder land connected to the reference potential pattern. On the circuit board, the electronic component is located on a downstream side in a transport direction of the circuit board during mounting of the piezoelectric element and the electronic component on the solder land, and the piezoelectric element is located on an upstream side in the transport direction.

31 Claims, 11 Drawing Sheets

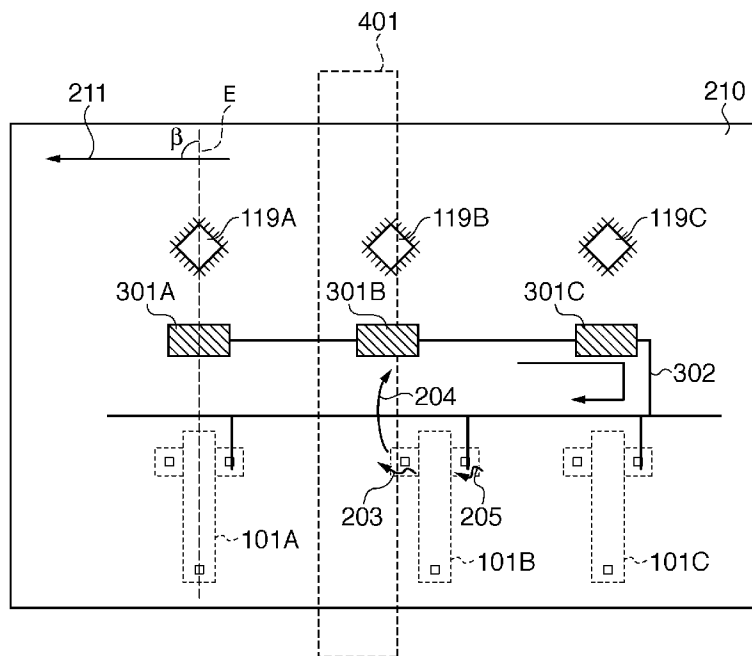


FIG. 2A

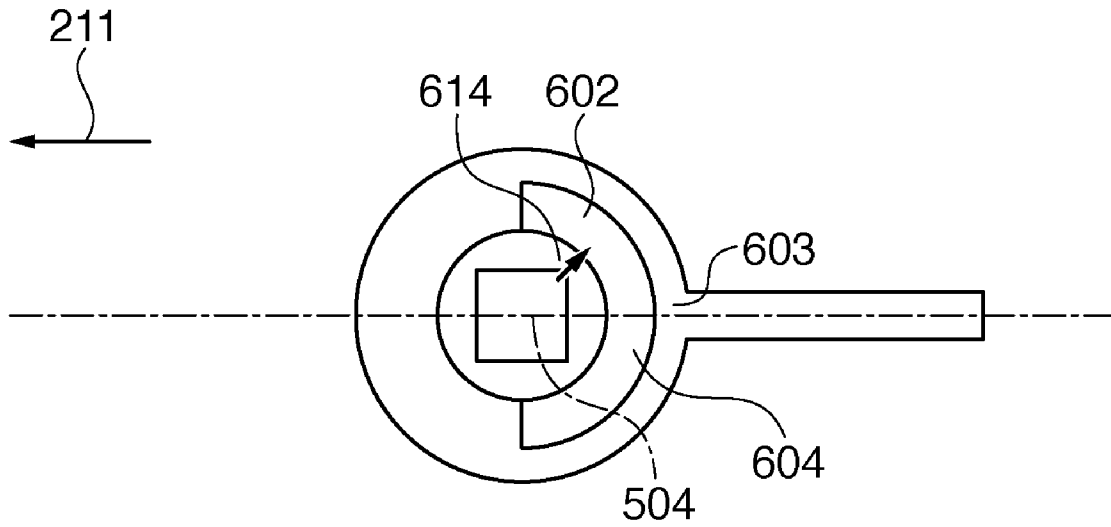


FIG. 2B

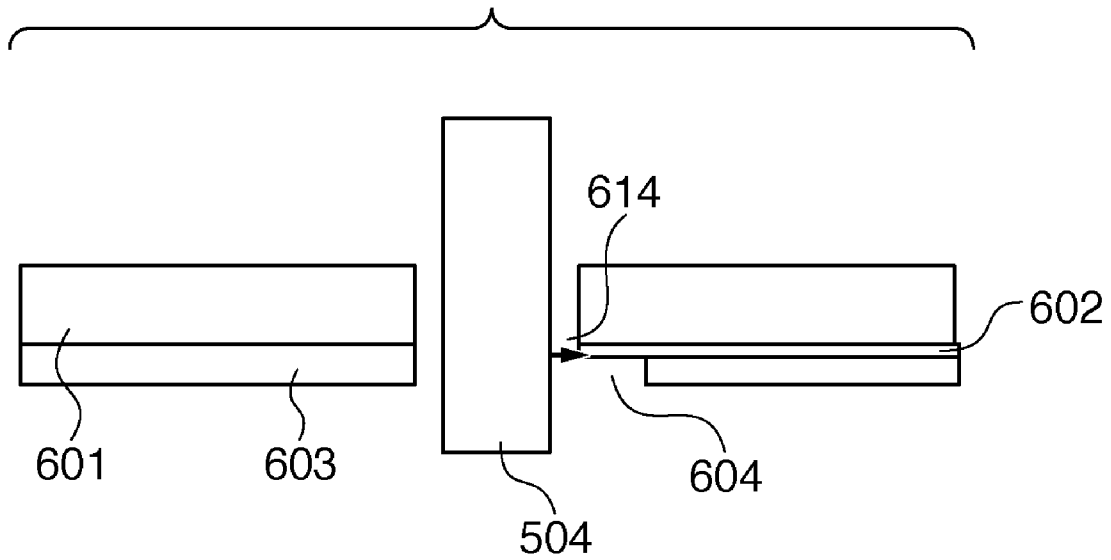


FIG. 3

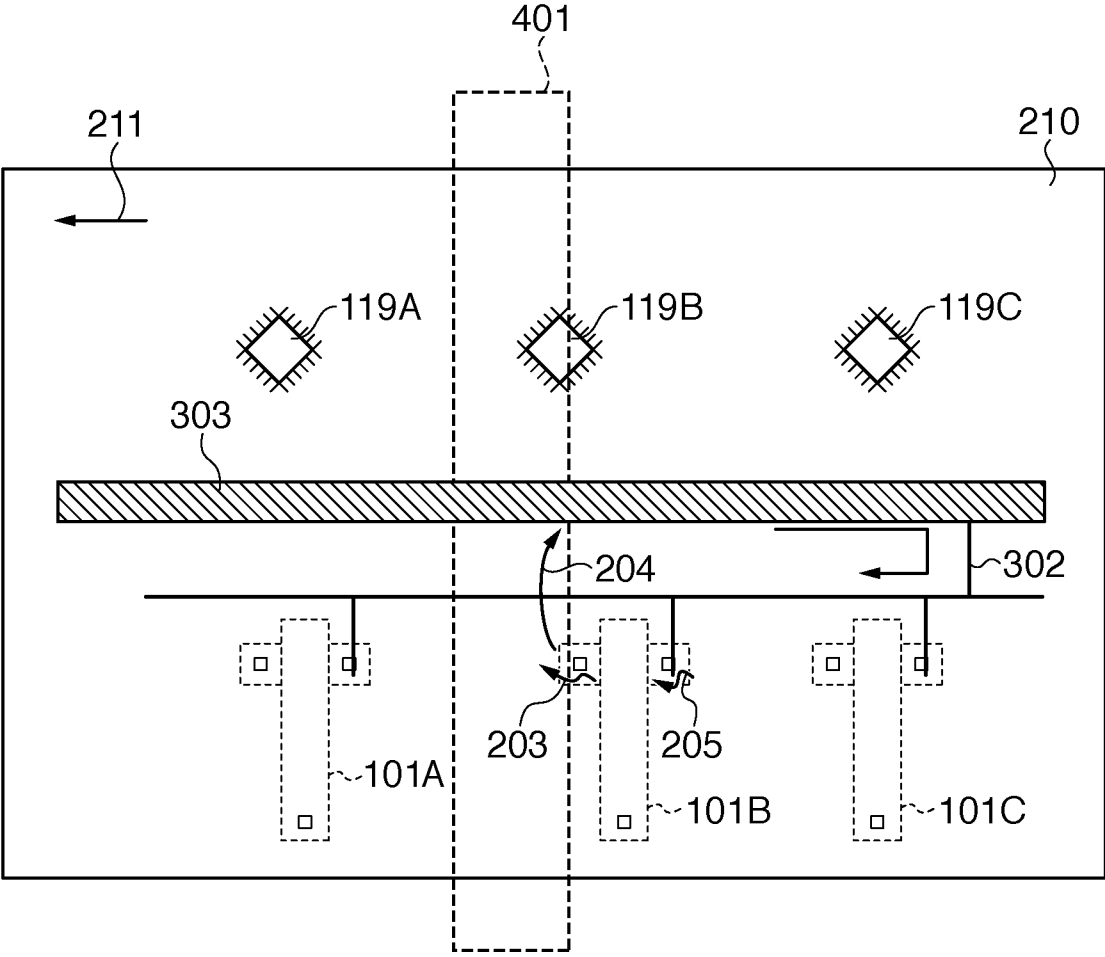


FIG. 4

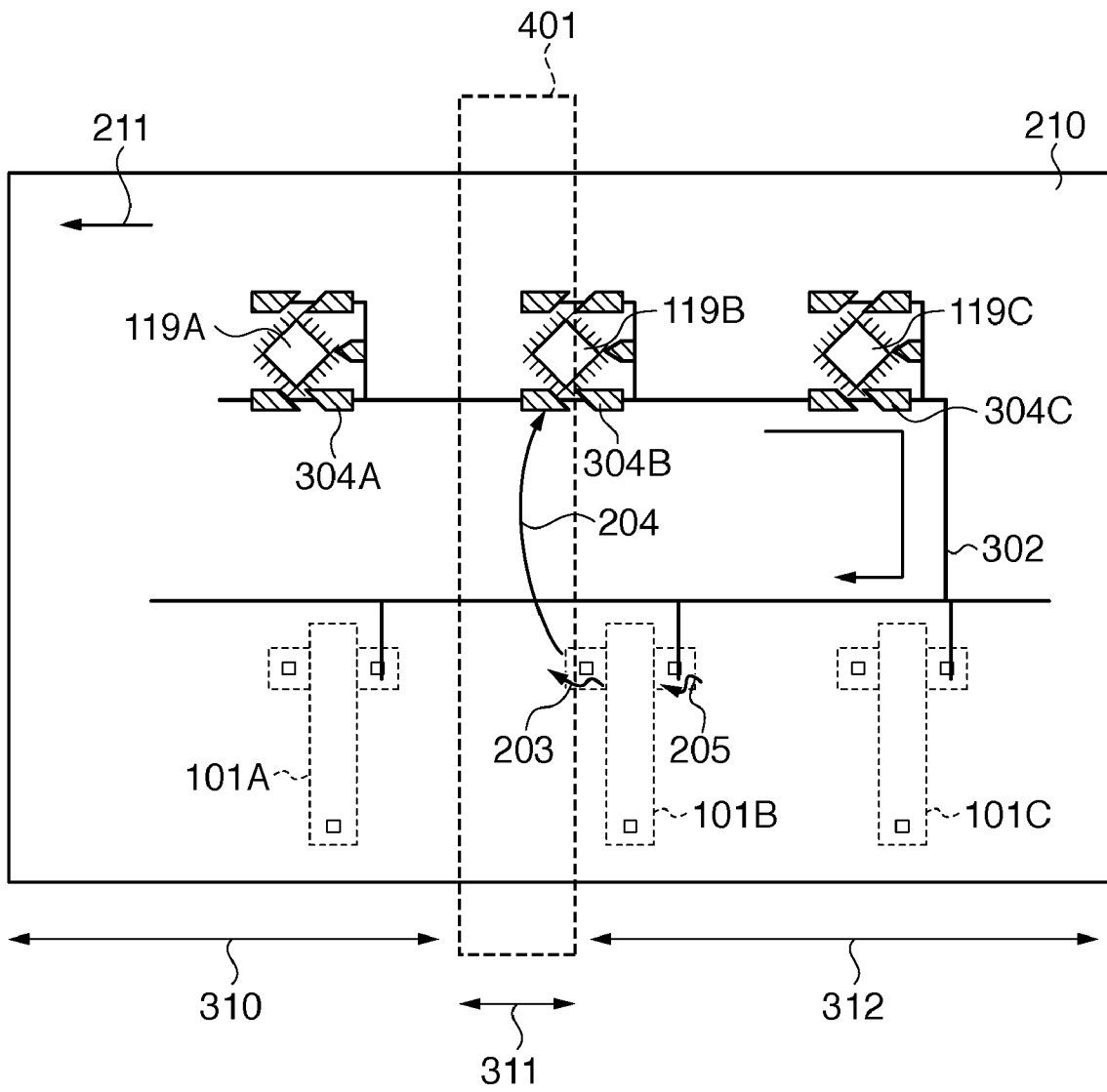


FIG. 5

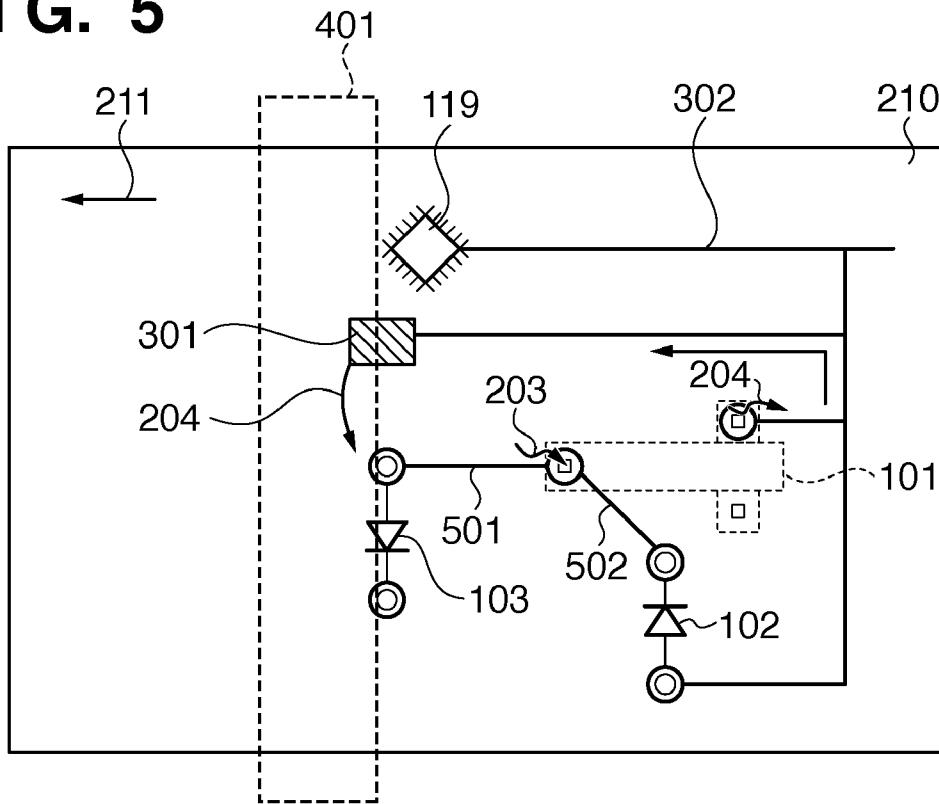


FIG. 6

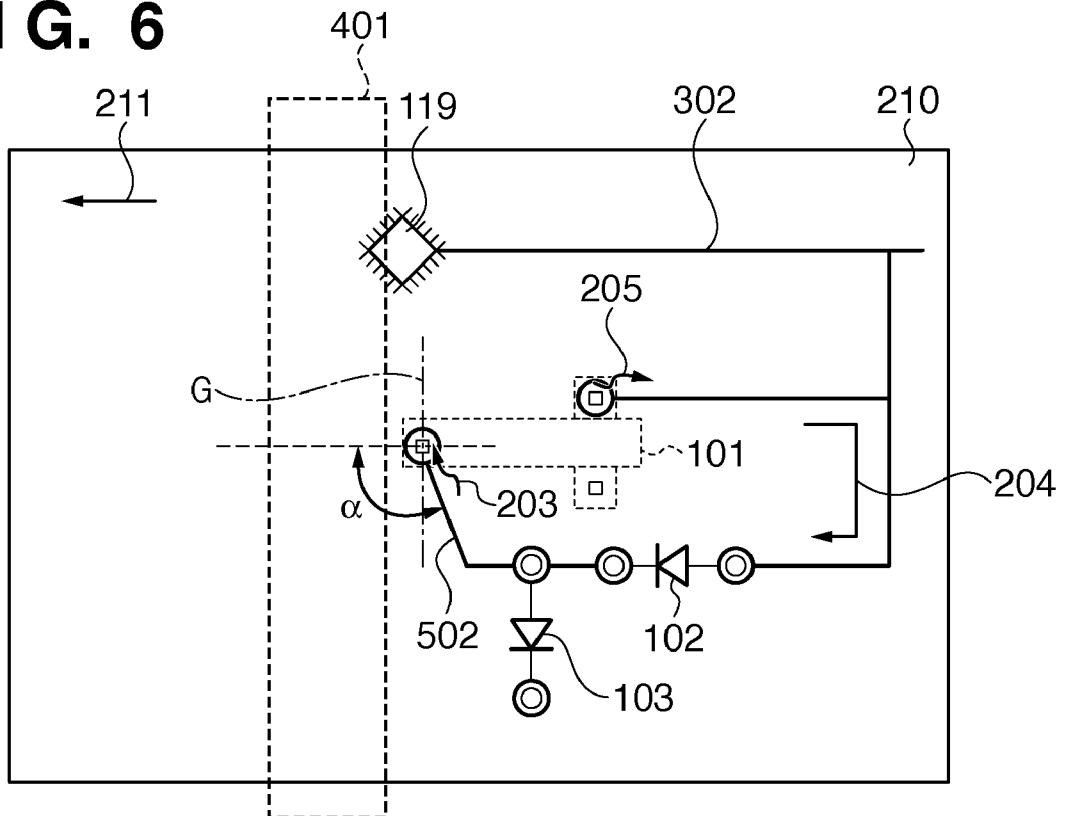


FIG. 7A

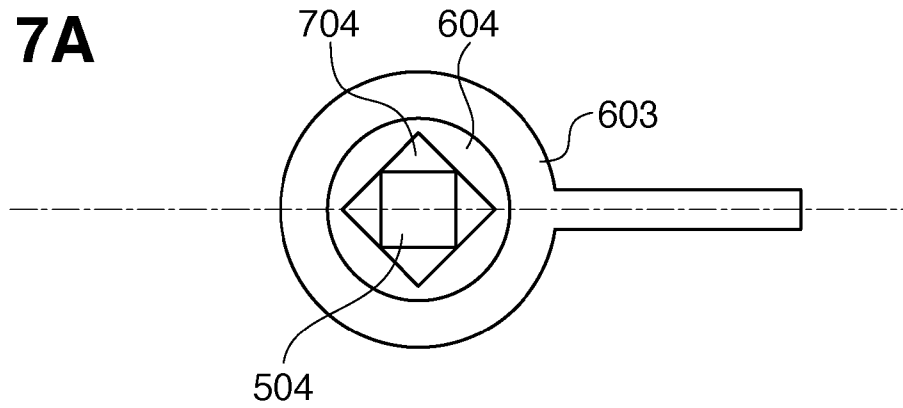


FIG. 7B

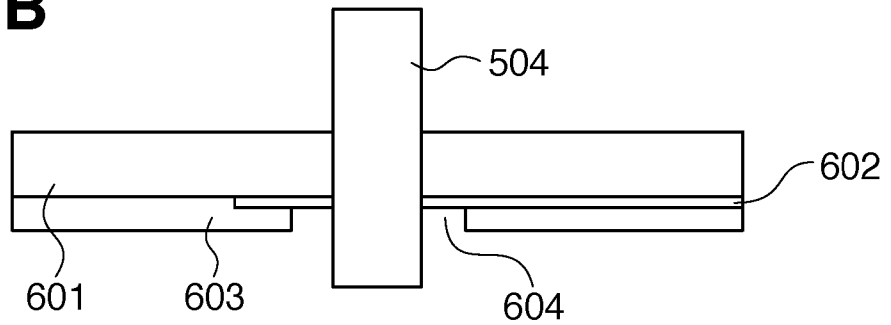


FIG. 8A

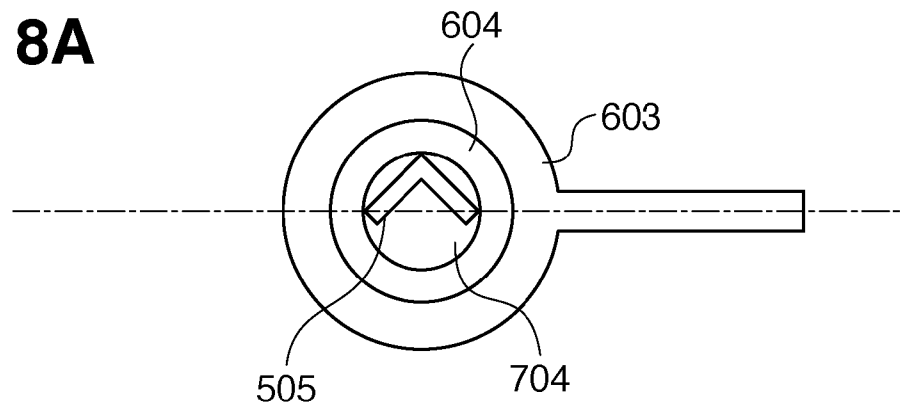


FIG. 8B

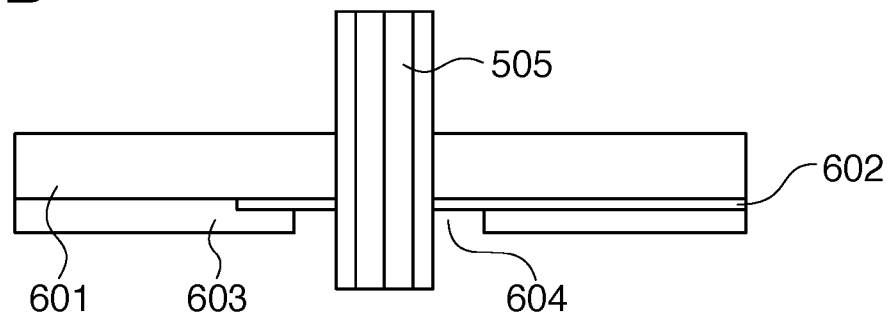


FIG. 9A

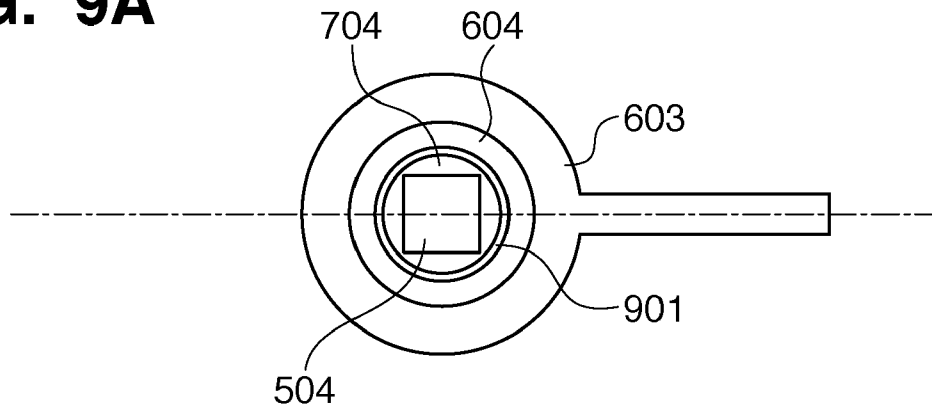


FIG. 9B

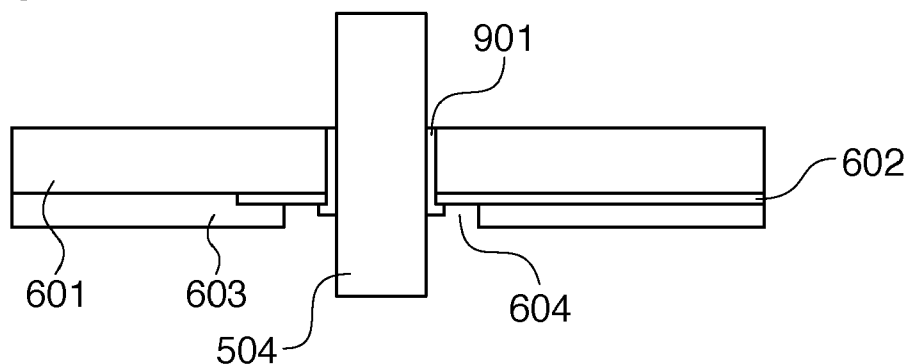


FIG. 10

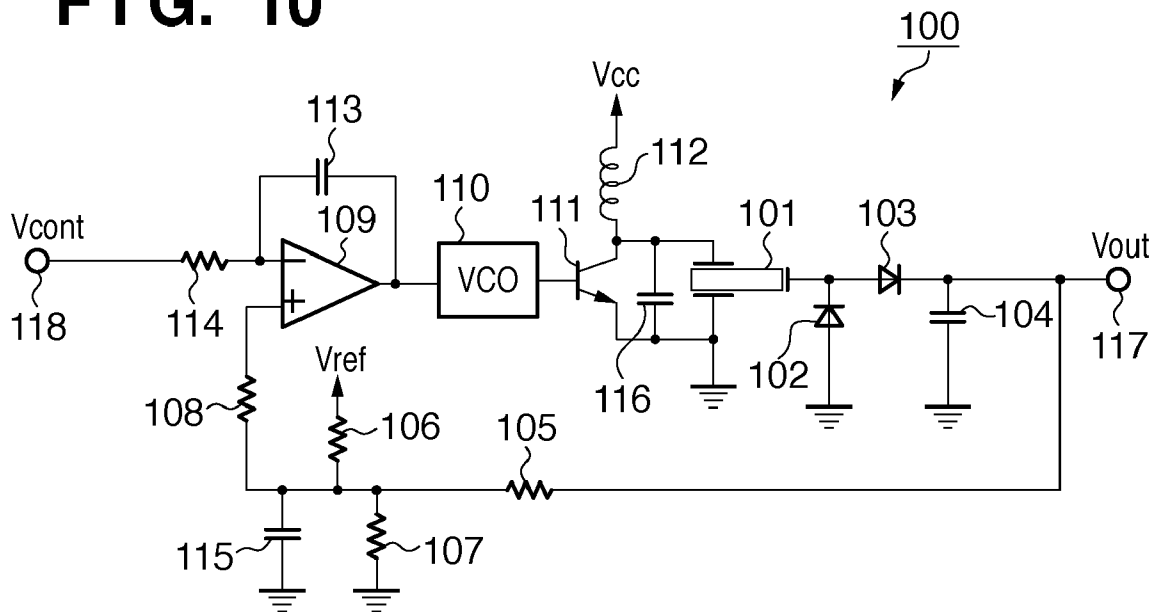


FIG. 11

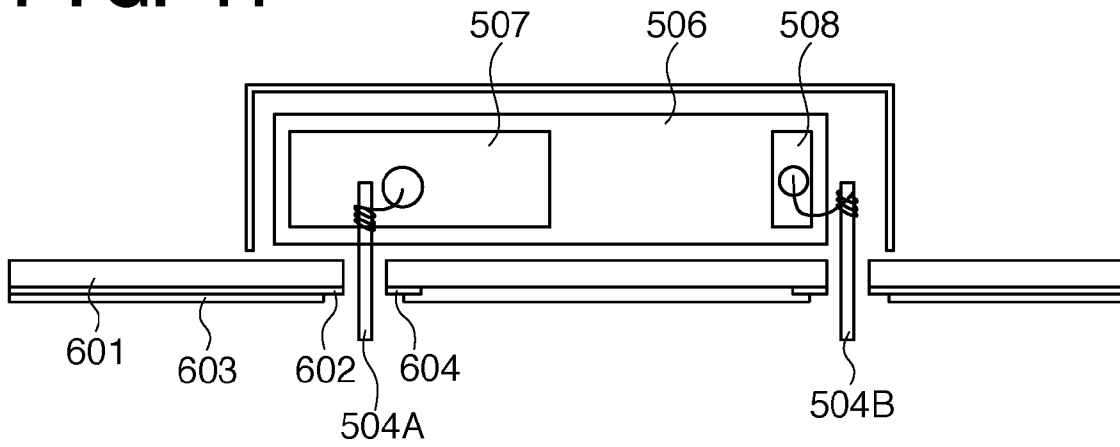


FIG. 12A

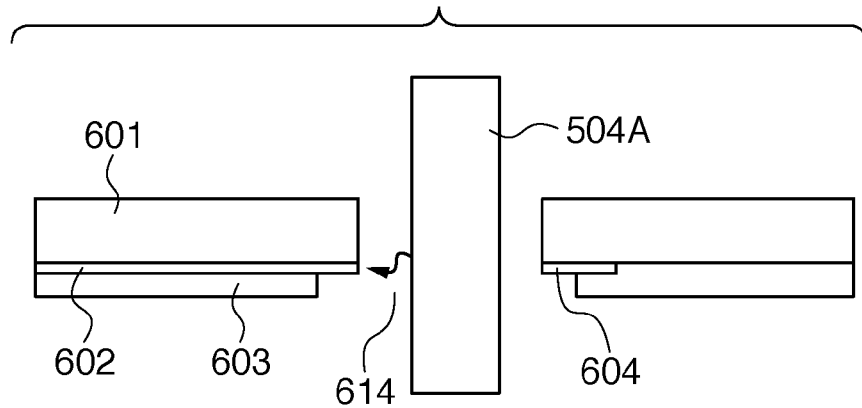


FIG. 12B

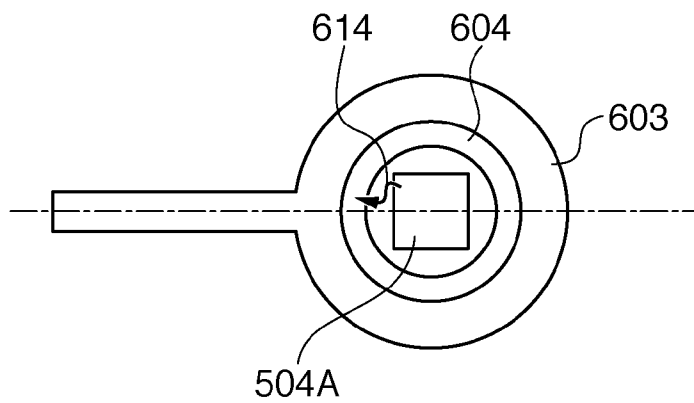


FIG. 13

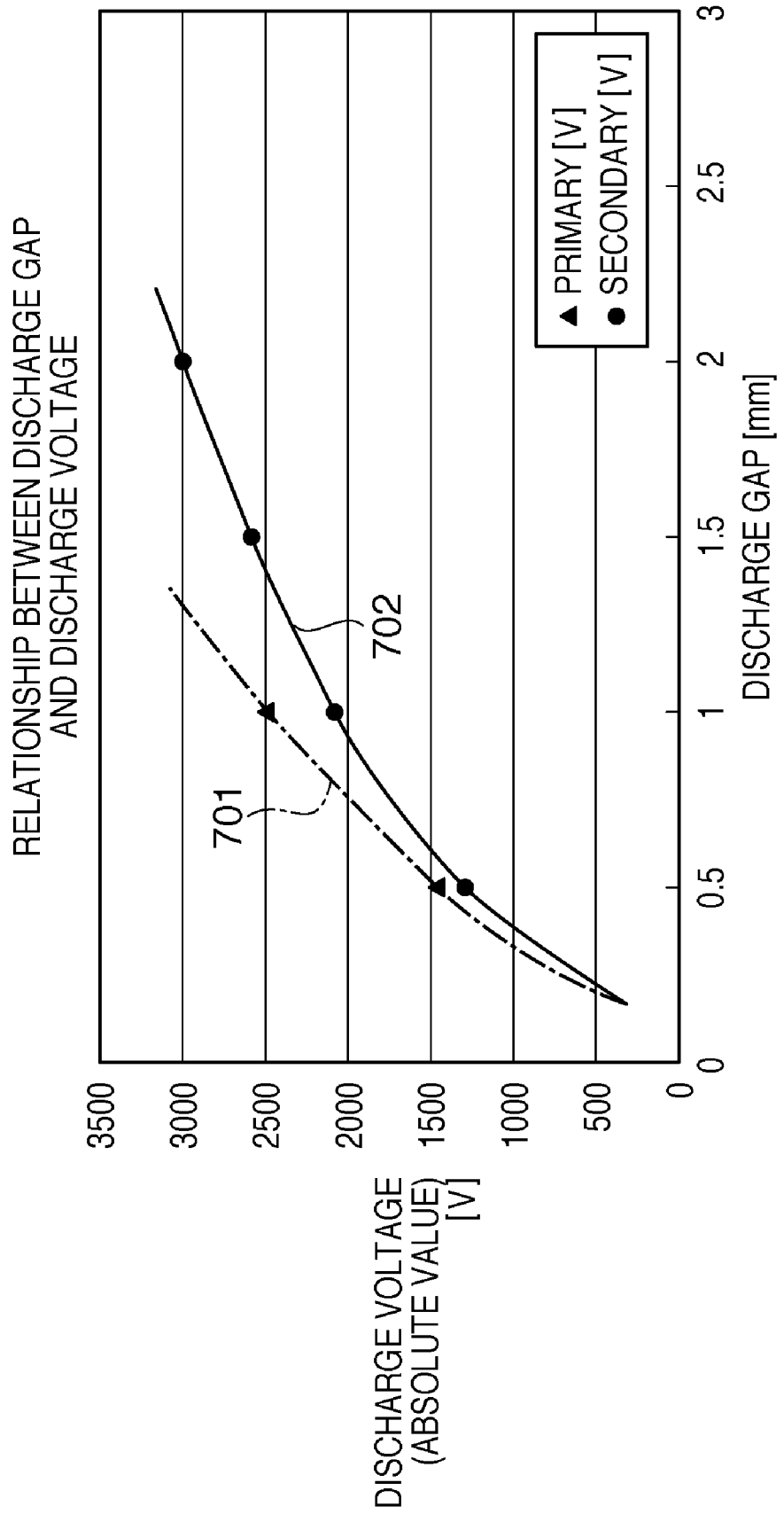


FIG. 14

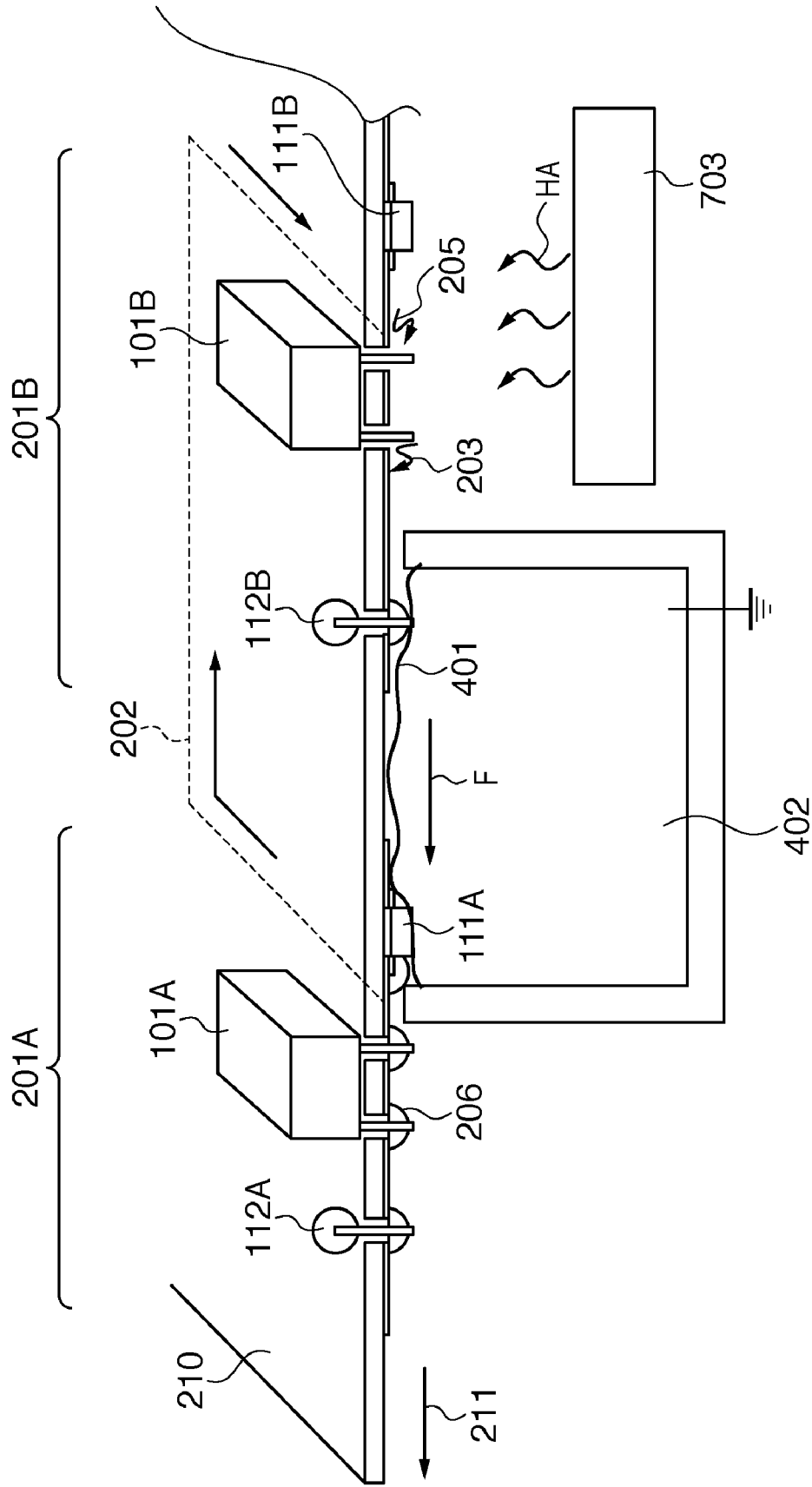
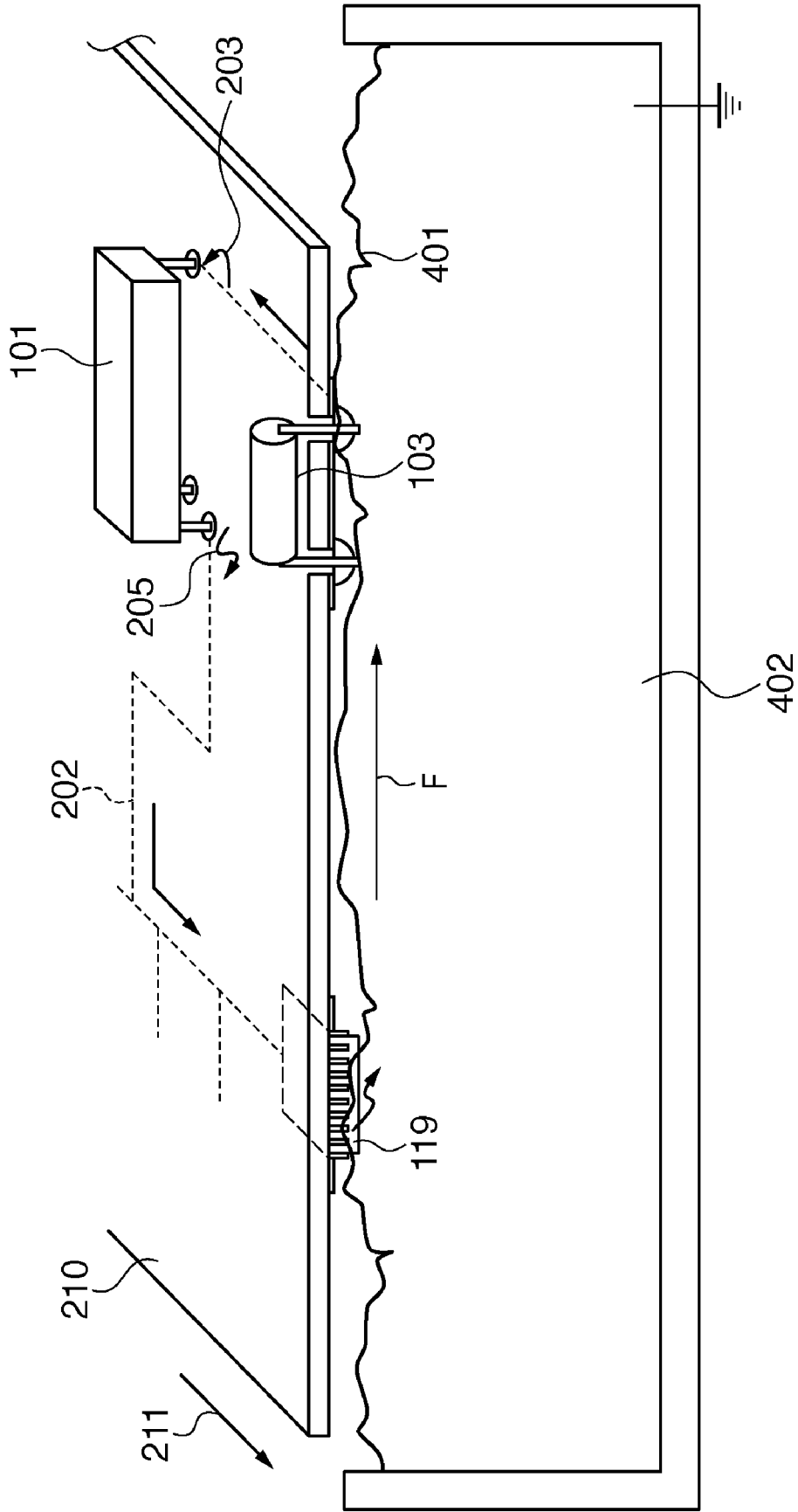


FIG. 15



PRINTED CIRCUIT BOARD EQUIPPED WITH PIEZOELECTRIC ELEMENT

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a printed circuit board with piezoelectric elements.

2. Description of the Related Art

In an electrophotographic image forming apparatus, for good image transfer to a sheet, a high voltage (a voltage of several hundred volts or more, which is higher than a commercial power supply voltage) is generally applied to a transfer roller, and a current of approximately 10 μ A is applied to the transfer roller. To generate such a high voltage, conventionally a wound-rotor type electromagnetic transformer has been used. The wound-rotor type electromagnetic transformer is, however, difficult to reduce in size and weight. To further reduce the size and weight of an electronic apparatus such as an image forming apparatus, the size and weight of a power supply that generates a high voltage must be reduced. To achieve a reduction in the size and weight of a power supply, the use of a piezoelectric transformer (a piezoelectric ceramic configured as a transformer with electrodes) is being considered instead of using the wound-rotor type electromagnetic transformer. A piezoelectric transformer is capable of generating a high voltage with higher efficiency than the electromagnetic transformer and furthermore does not require molding for providing isolation between primary and secondary electrodes. Thus, the piezoelectric transformer brings the advantage that the power supply is reduced in size and weight (Japanese Patent Laid-Open No. 11-206113).

SUMMARY OF THE INVENTION

For the manufacture of a circuit board that is incorporated into an electronic apparatus, flow soldering is known as a method for soldering electronic components to a printed circuit board. Flow soldering is a soldering method implemented by coating a flux to a printed circuit board with electronic components and then dipping the board into a flow soldering bath that contains molten solder. More specifically, soldering is implemented by forming a jet of molten solder (a solder jet flow) in a flow soldering bath and bringing a board into contact with the top of the solder jet flow. In the course of preheating and passage through the flow soldering bath in this flow soldering process, the piezoelectric transformer is heated to as high as several hundred degrees. A piezoelectric element that is heated to a high temperature generates a high voltage at a terminal of a piezoelectric transformer due to its pyroelectric effect. Specifically, a spark discharge is generated in a gap provided between a primary terminal of the piezoelectric transformer and a solder land. A discharge voltage at this time reaches a value of approximately several hundred to several thousand volts. Also, although the amount of charge accumulated on a secondary terminal of the piezoelectric transformer is small and thus does not develop into sparks, a discharge voltage of several hundred volts to several thousand volts is still generated at that terminal.

In contrast, electrostatic withstand voltages at terminals of electronic components (semiconductor components) such as LSIs and transistors are approximately on the order of several hundred volts. Thus, at the time of the above discharge generated due to the pyroelectric effect, semiconductor components that are direct extensions of solder lands provided for

the terminals of a piezoelectric transformer may be broken due to the application of a voltage that exceeds their electrostatic withstand voltages.

The present invention thus aims to solve at least one of such a problem and other problems. For example, the present invention enables a semiconductor component to be protected from discharge with the use of a low-cost and simple method, the discharge being generated from a piezoelectric element due to the pyroelectric effect of the element during a flow soldering process. Note that the other problems will be understood through the entire specification.

According to the present invention, an electronic apparatus includes, for example, a circuit board with an electronic component and a piezoelectric element, a reference potential pattern that gives a reference potential to at least one of the electronic component and the piezoelectric element, and a solder land connected to the reference potential pattern. On the circuit board, the electronic component is located on a downstream side in a transport direction of the circuit board during mounting of the piezoelectric element and the electronic component on a solder land, and the piezoelectric element is located on an upstream side in the transport direction.

Further features of the present invention will become apparent from the following description of exemplary embodiments (with reference to the attached drawings).

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a circuit diagram illustrating an example of a board layout of a piezoelectric transformer type high-voltage power supply apparatus according to a first embodiment.

FIG. 2A is a plan view illustrating the shape of a land relating to a terminal of a piezoelectric transformer.

FIG. 2B is a vertical cross-sectional view illustrating the shape of a land relating to a terminal of a piezoelectric transformer.

FIG. 3 is a circuit diagram illustrating an example of a board layout of a piezoelectric transformer type high-voltage power supply apparatus.

FIG. 4 is a circuit diagram illustrating an example of a board layout of a piezoelectric transformer type high-voltage power supply apparatus.

FIG. 5 is a circuit diagram illustrating an example of a board layout of a piezoelectric transformer type high-voltage power supply apparatus according to a fourth embodiment.

FIG. 6 is a circuit diagram illustrating an example of a board layout of a piezoelectric transformer type high-voltage power supply apparatus.

FIGS. 7A, 8A, and 9A are enlarged views of the vicinity of a portion where a terminal of a piezoelectric transformer 101 is inserted through a solder land 604 of a paper-phenolic resin plate 601.

FIGS. 7B, 8B, 9B are vertical cross-sectional views of the vicinity of a portion where the terminal of the piezoelectric transformer 101 is inserted through the solder land 604 of the paper-phenolic resin plate 601.

FIG. 10 is a circuit diagram of a piezoelectric transformer type high-voltage power supply apparatus for use in an image forming apparatus.

FIG. 11 illustrates the piezoelectric transformer 101 inserted into a printed circuit board.

FIG. 12A is an enlarged view of the vicinity of a primary terminal 504A of the piezoelectric transformer 101 and a solder land 604 of a paper-phenolic board.

FIG. 12B is a diagram of a printed circuit board in FIG. 12A as viewed from the solder side.

FIG. 13 illustrates an example of actual measurement results obtained by measuring a change in discharge voltage according to a discharge gap.

FIG. 14 is a diagram illustrating an undesirable effect of mounting associated with discharge generated due to the pyroelectric effect.

FIG. 15 is a diagram illustrating another example case of an undesirable effect of mounting associated with discharge generated due to the pyroelectric effect.

DESCRIPTION OF THE EMBODIMENTS

Now, embodiments of the present invention will be described. Individual embodiments described below will help understanding various concepts of the present invention such as superordinate, intermediate, and subordinate concepts. Also, the technical scope of the present invention is determined by the scope of the claims and is not limited by the following individual embodiments. Note that common parts in the drawings and the specification are denoted by the same reference numerals in order to simplify the description.

Related Technology

A high-voltage power supply apparatus 100 that outputs a positive voltage will be described as an example of an electronic apparatus with reference to FIG. 10. The high-voltage power supply apparatus 100 is, for example, used in an electrophotographic image forming apparatus and applies a high voltage to a transfer roller. The piezoelectric transformer 101 is adopted instead of a conventional wound-rotor type electromagnetic transformer. The output of the piezoelectric transformer 101 is rectified and smoothed into a positive voltage by a rectifier smoothing circuit. The rectifier smoothing circuit is constituted by rectifier diodes 102 and 103 and a high-voltage capacitor 104. The output voltage of the piezoelectric transformer 101 is output from an output terminal 117 that is connected to a path elongated from the piezoelectric transformer 101, and is supplied to a load (for example, a transfer roller (not shown)). Note that the output voltage is divided by resistors 105, 106, and 107 and is input into a capacitor 115 and into a non-inverting input terminal (positive terminal) of an operational amplifier 109 via a protective resistor 108.

On the other hand, an inverting input terminal (negative terminal) of the operational amplifier 109 receives an analog signal (a control signal (Vcont) of the high-voltage power supply apparatus) that has been input from an input terminal 118, via a resistor 114. The operational amplifier 109, the resistor 114, and a capacitor 113 serve as an integrating circuit. Specifically, the control signal Vcont that is smoothed according to an integration time constant determined by the constants of components of the resistor 114 and the capacitor 113 is input into the operational amplifier 109. The output terminal of the operational amplifier 109 is connected to a voltage controlled oscillator (VCO) 110. The voltage controlled oscillator 110 is an example of an oscillator that sets the frequency of its output signal variable according to the input control signal.

The output terminal of the voltage controlled oscillator 110 is connected to the gate of a field-effect transistor 111. The field-effect transistor 111 is an example of a switching element that is driven by the output signal of an oscillator. The drain of the field-effect transistor 111 is connected via an inductor 112 to a power supply Vcc (for example, +24 volts) and is grounded via a capacitor 116. The inductor 112 is an element that is connected between a switching element and a power supply and that is an example of an element having an inductance component to which a voltage is intermittently

applied by drive of the switching element. The transistor drain is further connected to one of primary electrodes of the piezoelectric transformer 101. The other primary electrode of the piezoelectric transformer 101 is grounded. The source of the field-effect transistor 111 is also grounded.

The voltage controlled oscillator 110 performs switching of the field-effect transistor 111 at a frequency according to the output voltage of the operational amplifier 109. The inductor 112 and the capacitor 116 constitute a resonance circuit. The voltage amplified by this resonance circuit is supplied to the primary side of the piezoelectric transformer 101. As described above, the piezoelectric transformer 101 is connected to a connecting point between the switching element and the element having an inductance component, and upon application of a signal that oscillates at a specified resonance frequency, outputs a voltage according to the frequency characteristics of that signal.

As illustrated here, multiple semiconductor components including the field-effect transistor 111, the operational amplifier 109, and the voltage controlled oscillator (VCO) 110 are used to actuate the piezoelectric transformer 101. Also, the piezoelectric transformer type high-voltage power supply apparatus 100 used in an image forming apparatus or the like often has multiple high-voltage generation circuits formed on a single printed circuit board, so its wiring layout is very complicated in many cases.

A piezoelectric element used as the piezoelectric transformer 101 is manufactured by applying a strong DC electric field to a high-temperature sintered polycrystalline ferroelectric while applying heat at a temperature of several hundred degrees, and thereby aligning an electric dipole in the ferroelectric in a certain direction. Due to the nature of the ferroelectric, a dipole moment still remains after removal of the electric field, so the piezoelectric element has high piezoelectricity at ordinary temperatures.

FIG. 11 illustrates an example configuration of the piezoelectric transformer 101, which may be a piezoelectric element with any other configuration. A piezoelectric ceramic element 506 has a primary electrode 507 and a secondary electrode 508 evaporated thereon with a silver paste. The primary electrode 507 and the secondary electrode 508 are connected to a metallic primary terminal 504A and a metallic secondary terminal 504B, respectively, with gold filaments, and those connecting points are conducting via a solder. Now, a printed circuit board will be described using a commonly-used single-layer paper-phenolic board by way of example. The paper-phenolic board includes a copper foil 602 and a resist 603 as a wire on the surface of a paper-phenolic resin plate 601. A layer formed by the copper foil 602 and the resist 603 is referred to as a solder resist layer. The paper-phenolic board has holes formed at connecting portions between component terminals and the wiring portion. A solder land 604 for enabling soldering is formed around each hole. The solder land 604 is formed by stripping off the resist 603 by means of etching and thereby exposing the copper foil 602.

FIGS. 12A and 12B illustrate the primary terminal 504A of the piezoelectric transformer 101. As described previously, when the printed circuit board with the piezoelectric transformer 101 is transported through a flow soldering bath, the piezoelectric ceramic element 506 is heated by a heater used in the course of preheating and by the heat of a solder jet flow in the flow soldering bath. Then, charge is generated due to a pyroelectric effect at the primary electrode 507 and the secondary electrode 508 of the heated piezoelectric ceramic element 506. That is, a voltage is generated at the primary terminal 504A and the secondary terminal 504B. The pyroelectric effect refers to an electric polarization phenomenon

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that occurs upon the heating or cooling of a crystal. While a pyroelectric material such as a piezoelectric element causes spontaneous polarization by a change in temperature, such polarization is neutralized without a change in temperature. The occurrence of such polarization causes an interior accumulated charge to be generated at electrodes attached across the element.

If there is a gap (hereinafter referred to as a “discharge gap”) between the primary terminal **504A** and the solder land **604**, a high voltage generated due to the pyroelectric effect develops into a spark discharge **614** and is transmitted through the gap. Specifically, charge moves to the solder land **604** and the copper foil **602**, which results in a dramatic fluctuation in the potential between the primary terminal **504A** and the solder land **604**.

Referring to FIG. 13, both a discharge characteristic **701** of the primary terminal **504A** and a discharge characteristic **702** of the secondary terminal **504B** tend to show a higher absolute value for the discharge voltage as the discharge gap increases. Note that the polarity of the discharge voltage varies depending on the polarity of the voltage applied during the polarization of the piezoelectric ceramic element **506**. By way of example, the piezoelectric transformer **101** as used herein outputs a positive discharge voltage from the primary terminal **504A** and a negative discharge voltage from the secondary terminal **504B**.

Referring to FIG. 14, on a printed circuit board **210**, piezoelectric transformers **101A** and **101B**, field-effect transistors **111A** and **111B** as semiconductor components, and inductors **112A** and **112B** are mounted in advance in predetermined positions, using an automatic insertion machine or by manual insertion. In a flow soldering implementation process, the printed circuit board **210** is transported in a travelling direction indicated by arrow **211**. The printed circuit board **210** is first preheated by a heater **703** and then transmitted through a solder jet flow **401** in a flow soldering bath **402**. Thereby, soldering is accomplished.

Assume that a pattern that gives a reference potential to the piezoelectric transformers **101A** and **101B** and a pattern of source terminals of the field-effect transistors **111A** and **111B** are connected through a wire **202** on the printed circuit board **210**, so that both of the patterns have a common potential.

The piezoelectric transformer **101A** and the inductor **112A** that belong to a circuit block **201A** have already passed through the solder jet flow **401**, so soldering **206** is completed. The field-effect transistor **111A** that belongs to the circuit block **201A** and the inductor **112B** that belongs to the circuit block **201B** are passing through the solder jet flow **401**. Furthermore, the piezoelectric transformer **101B** and the field-effect transistor **111B** that belong to the circuit block **201B** are in the course of preheating before passing through the solder jet flow.

If the piezoelectric transformer **101B** in the course of preheating is rapidly heated by hot air HA from the heater **703**, the pyroelectric effect causes a spark discharge **203** to be generated from the terminal of the not-yet-soldered piezoelectric transformer **101B** to the land. The charge (discharge current) of the spark discharge **203** is transmitted to the terminal of the inductor **112B** that is passing through the solder jet flow **401** and to the land. The charge of the spark discharge **203** is further transmitted through the solder jet flow **401** along arrow F to the gate terminal of the field-effect transistor **111A** that is passing through the solder jet flow **401**. The charge that has passed through the field-effect transistor **111A** is transmitted via the wire **202**, develops into a spark discharge **205**, and returns to the reference terminal of the piezoelectric transformer **101B**. The above described is a

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travel path (discharge path) of the charge that comes out of the piezoelectric transformer **101B** due to discharge. Upon generation of discharge, the potential at the gate terminal of the field-effect transistor **111A** rises rapidly relative to the source terminal thereof that is connected to the reference potential of the printed circuit board **210**. Thus, if this potential exceeds an electrostatic withstand voltage of the gate terminal, the piezoelectric transformer **101B** will be broken in excess of the electrostatic withstand voltage.

Referring now to FIG. 15, on another printed circuit board **210**, a piezoelectric transformer **101**, a semiconductor component **119**, and a rectifier diode **103** that is connected via a wire to a secondary land of the piezoelectric transformer **101** are mounted in advance, using an automatic insertion machine or by manual insertion. The semiconductor component **119** is, for example, a VCO circuit, an operational amplifier, or an IC obtained by combining those components. In a flow soldering bath **402**, soldering is accomplished by transporting the board in a board travelling direction (the direction indicated by arrow **211**) for passage through the solder jet flow **401**. In the state illustrated in FIG. 15, the piezoelectric transformer **101** is in the course of preheating and has not yet reached the solder jet flow **401**. A pattern that gives a reference potential to the piezoelectric transformer **101** and a pattern that gives a reference potential to the semiconductor component **119** are connected via a wire **202** on the printed circuit board **210**, so that both of the patterns have a common potential.

If the piezoelectric transformer **101** in the course of preheating is rapidly heated by a heater or by the heat of the solder jet flow **401**, the pyroelectric effect causes the spark discharge **203** to be generated from the secondary terminal of the not-yet-soldered piezoelectric transformer **101** to the land. The charge of the spark discharge **203** is transmitted to the terminal of the rectifier diode **103** that is passing through the solder jet flow **401** and to the land. The charge is further transmitted through the solder jet flow **401** as indicated by arrow F to the terminal of the semiconductor component **119** that is passing through the solder jet flow **401**. The charge that has passed through the semiconductor component **119** develops into a spark discharge **205** via the wire **202**. The spark discharge **205** returns to a primary reference terminal of the piezoelectric transformer **101**.

A travel path of the charge that comes out of the piezoelectric transformer **101** due to discharge is also described using the model as described above. Also in this discharge process, the potential at the terminal of the semiconductor component **119** rises rapidly relative to the reference potential thereof. Thus, if this potential exceeds the electrostatic withstand voltage of the terminal, the semiconductor component **119** will be broken.

As described with reference to FIGS. 14 and 15, the solder jet flow **401** in the flow soldering bath is disposed perpendicular to the travelling direction (the direction indicated by arrow **211**) of the printed circuit board **210**. Thus, even if a solder land for a terminal of the piezoelectric transformer **101** and a semiconductor component are not in direct contact through a pattern, they may possibly be brought into connection through the solder jet flow **401**. Moreover, since the flow soldering bath is generally grounded to the earth, the solder jet flow **401** is also considered as being grounded to the earth from a broad view. However, the reference potential of the printed circuit board **210** that is passing through the flow soldering bath **402** is in a floating state unless the board is directly grounded to the earth or brought into contact with the flow soldering bath **402**. Therefore, if discharge is generated due to the pyroelectric effect from the piezoelectric trans-

former **101**, the discharge current will flow through a lower impedance pattern or a lower impedance component terminal because a discharge destination pattern or potential is in a floating state relative to the earth.

The following two methods, for example, are conceivable as a method for restraining breakage of the semiconductor component **119** due to discharge caused by the pyroelectric effect. The first method is to first solder components other than the piezoelectric transformer **101** and then manually solder the piezoelectric transformer **101** afterwards. The second method is to establish a short circuit across terminals (electrodes) of the piezoelectric transformer **101** using a conductive member during solder mounting, thereby creating a contact discharge path.

The former method has the disadvantage of increased mounting cost because of the needs of manpower and time, particularly in the case of such a large-scale high-voltage power supply apparatus that has multiple piezoelectric transformers **101** mounted on a single printed circuit board **210**. The latter method has the advantage of not requiring manpower. The latter method may be implemented if there is a conductive member that has excellent heat resistance and excellent durability in order to repeatedly establish a short circuit across the terminals of the piezoelectric transformer **101** in a high-temperature environment. However, if such a conductive member falls off during mounting or causes a contact failure, the semiconductor component **119** may not be adequately protected from discharge. Thus, the latter method is not sufficient. In view of the above, embodiments described below propose methods for manufacturing an electronic apparatus that enables a semiconductor component to be protected from discharge with use of a low-cost and simple method.

FIRST EMBODIMENT

The present invention is applicable to any electronic apparatus that includes a printed circuit board with a piezoelectric element and a semiconductor component, and the electronic apparatus does not need to be a high-voltage power supply apparatus. The present invention is also effective for a high-voltage power supply apparatus that outputs either a positive or negative voltage. Here, a high-voltage power supply apparatus that outputs a positive voltage will be described by way of example.

Piezoelectric transformers **101A**, **101B**, and **101C** and semiconductor components **119A**, **119B**, and **119C** illustrated in FIG. 1 are circuit components for forming different circuit blocks. This does not mean that the piezoelectric transformer **101A** and the semiconductor component **119A**, for example, constitute the same circuit block. In the present embodiment, the piezoelectric transformers **101A**, **101B**, and **101C** and the semiconductor components **119A**, **119B**, and **119C** are located parallel to a travelling direction (the direction indicated by arrow **211**) of a printed circuit board **210** during a solder mounting process. Specifically, the semiconductor component **119A** and the piezoelectric transformer **101A** are located on the printed circuit board **210** so that a straight line E that connects the semiconductor component **119A** and the piezoelectric transformer **101A** is approximately orthogonal to the travelling direction of the printed circuit board **210** during a soldering process. In other words, the travelling direction and the straight line E form an angle β of approximately 90 degrees. The same applies to the semiconductor component **119B** and the piezoelectric transformer **101B**. And, the same also applies to the semiconductor component **119C** and the piezoelectric transformer **101C**.

Moreover, a reference potential pattern **302** for giving a reference potential to the piezoelectric transformers **101A**, **101B**, and **101C** is located between the piezoelectric transformers **101A**, **101B**, and **101C** and the semiconductor component **119A**, **119B**, and **119C**. A resist of the reference potential pattern **302** is partly stripped off so as to expose some wiring portions, and the exposed wiring portions form solder lands **301A**, **301B**, and **301C**. The solder lands **301A**, **301B**, and **301C** are located so as to suppress charge on the terminals of the piezoelectric transformers **101A**, **101B**, and **101C** from travelling to the semiconductor components **119A**, **119B**, and **119C** during passage through a solder jet flow **401** in a flow soldering bath. Assume that the reference potential pattern **302** for the piezoelectric transformers is connected to a ground line.

The spark discharge **203** generated from the terminal of the piezoelectric transformer **101B**, for example, passes into the solder land **301B** connected to the reference potential pattern **302** for the piezoelectric transformer **101B** through the solder jet flow **401** in the flow soldering bath. Thereafter, the charge resulting from the spark discharge **203** comes back as a spark discharge **205** to the reference terminal of the piezoelectric transformer **101B**. In this way, the discharge path of the discharge current is formed by the piezoelectric transformer **101B**, the solder jet flow **401**, the solder land **301B**, and the reference potential pattern **302**. In particular, the provision of the solder land **301B** between the semiconductor component **119B** and the piezoelectric transformer **101B** suppresses passage of the discharge current to the semiconductor component **119B**.

Moreover, as for the land shape of sites where components are connected to the printed circuit board **210**, the adoption of a land shape illustrated in FIGS. 2A and 2B enables control of the direction of discharge from a terminal **504**. For example, if a solder land **604** is formed by stripping off the right half of a doughnut-shaped resist **603** and thereby exposing a copper foil **602** of a wiring portion, a discharge path is formed in a location where the terminal **504** is closest to the solder land **604**. If the solder land **604** is located behind the terminal **504** in the travelling direction of the printed circuit board **210** (the direction indicated by arrow **211**), the timing of soldering of a discharge destination may be delayed to later than the timing of discharge.

As described above, a solder land that is connected to a reference potential pattern is provided between a semiconductor component and a piezoelectric element so that a discharge current generated at the piezoelectric element due to the pyroelectric effect is restrained from flowing into the semiconductor component during the soldering process using a solder jet flow. In other words, a discharge path is formed by the piezoelectric element, the land, the reference potential pattern, and the solder jet flow. It is thus possible to relieve the discharge current generated at the piezoelectric element due to the pyroelectric effect to the discharge path during the soldering process using the solder jet flow. This enables a semiconductor component to be protected from discharge with a low-cost and simple method. This further decreases the probability of failure of a semiconductor component, thus improving the yield of an electronic apparatus such as a high-voltage power supply apparatus.

The reference potential pattern **302** may be a ground pattern for a piezoelectric transformer or a semiconductor component that are located over a wide range on the printed circuit board **210**, or may be a power supply voltage pattern for a semiconductor component. In this case, the reference potential pattern **302** that forms part of the discharge path may be implemented in a relatively simple pattern design.

While the present embodiment has been described using a model that generates discharge from a primary terminal of a piezoelectric transformer, the present invention is also effective for discharge generated from a secondary terminal of a piezoelectric transformer. This applies to other embodiments described below. The present embodiment has been described using the model in which the three piezoelectric transformers and the three semiconductor components are mounted on the printed circuit board **210**. However, a similar effect to that in the present embodiment is also attained with a printed circuit board that includes at least one piezoelectric transformer and at least one semiconductor component.

SECOND EMBODIMENT

In the first embodiment, the semiconductor components are protected from discharge by providing the solder lands **301A**, **301B**, and **301C** between the semiconductor components and the piezoelectric elements. In a second embodiment, a soldering enabling pattern is adopted instead of the solder lands **301A**, **301B**, and **301C**.

A soldering enabling pattern **303** illustrated in FIG. **3** is a kind of land formed by exposing a wiring portion of a reference potential pattern **302**. A single or multiple soldering enabling patterns **303** are located generally in parallel with a board travelling direction (the direction indicated by arrow **211**) during solder mounting. That is, the soldering enabling pattern **303** that is part of a reference potential pattern and that extends in the travelling direction of a printed circuit board during the soldering process is adopted as a land that forms part of a discharge path. To simplify the description, FIG. **3** illustrates a single soldering enabling pattern **303**. Note that the reference potential pattern **302** may be a pattern that gives a reference potential to a piezoelectric transformer **101B** or may be a pattern that gives a reference potential to a semiconductor component **119B**.

With such provision of the soldering enabling pattern **303** connected to a reference potential pattern between a semiconductor component and a piezoelectric element, a discharge path is formed by the piezoelectric element, the soldering enabling pattern **303**, the reference potential pattern **302**, and a solder jet flow **401**. Thus, the second embodiment also attains a similar effect to that in the first embodiment. Moreover, in the second embodiment, the soldering enabling pattern **303** that extends over a predetermined area makes more stable contact with discontinuous irregularities in the solder jet flow **401** than in the first embodiment. Thus, it may be said that the second embodiment improves the reliability of protection of a semiconductor component.

THIRD EMBODIMENT

A major difference of a third embodiment illustrated in FIG. **4** from the first and second embodiments is that anti-solder bridging patterns **304A**, **304B**, and **304C** that are provided at end portions of semiconductor components are adopted as a discharge path in order to restrain the occurrence of solder bridging during the soldering process. Note that the anti-solder bridging patterns **304A**, **304B**, and **304C** may also be referred to as dummy lands or dummy pads. The anti-solder bridging patterns **304A**, **304B**, and **304C** are connected to ground lines or power supply lines through which a reference potential is given to semiconductor components. Note that the anti-solder bridging patterns **304A**, **304B**, and **304C** are formed by stripping off a resist **603** and thereby exposing a copper foil **602** of wiring portions.

As described above, the anti-solder bridging patterns **304A**, **304B**, and **304C** connected to a reference potential pattern are provided between the semiconductor components and the piezoelectric elements. Accordingly, a discharge path is formed by the piezoelectric elements, the anti-solder bridging patterns **304A**, **304B**, and **304C**, the reference potential pattern **302**, and a solder jet flow **401**.

The third embodiment thus attains similar effects to those in the first and second embodiments. The third embodiment may further attain a higher protection effect if the anti-solder bridging patterns **304A**, **304B**, and **304C** are shaped so as to surround semiconductor components to be protected. Of course, the anti-solder bridging patterns **304A**, **304B**, and **304C** of the third embodiment may be combined with the first or second embodiment. In such a case, an even higher protection effect will be attained.

Moreover, in some cases such as the case of a compact printed circuit board, it may be difficult in terms of layout to locate a land or a pattern as described in the first or second embodiment. The anti-solder bridging patterns **304A**, **304B**, and **304C** according to the third embodiment are advantageous in this respect, since they may be formed on a compact printed circuit board or the like.

FOURTH EMBODIMENT

While the present invention is effective for any high-voltage power supply apparatus that outputs either a positive or negative voltage, the present embodiment is described using a high-voltage power supply apparatus that outputs a positive voltage by way of example. The description is based on the assumption that the terminal at which a voltage is generated due to the pyroelectric effect is a secondary terminal, and the generated voltage has a negative polarity.

In a fourth embodiment illustrated in FIG. **5**, a semiconductor component **119** is located in front of a piezoelectric transformer **101** in a travelling direction of a printed circuit board **210** (the direction indicated by arrow **211**) during the soldering process. In addition, an elongating pattern **501** is wired that is elongated from a terminal land of the piezoelectric transformer **101** forward in the travelling direction to a terminal of a rectifier diode **103**, for example. Note that the terminal land of the piezoelectric transformer **101** and one end of a diode **102** are connected via an elongating pattern **502** that is elongated from the terminal land of the piezoelectric transformer **101** in generally an opposite direction from the travelling direction. The other end of the diode **102** is connected to a reference potential pattern **302**. In the fourth embodiment, the reference potential pattern **302** for giving a reference potential to the piezoelectric transformer **101** or the semiconductor component **119** is located between the piezoelectric transformer **101** and the semiconductor component **119**. Moreover, a solder land **301** is formed by partly stripping off the resist of the reference potential pattern **302** and thereby exposing a wiring portion.

A spark discharge **203** generated due to the pyroelectric effect of the piezoelectric transformer **101** (the discharge current that has a negative polarity in the present example flows in a direction toward the piezoelectric transformer **101**) passes into the reference potential pattern **302** through the elongating pattern **501** and a solder jet flow **401**. The charge resulting from the spark discharge **203** develops into a spark discharge **204** and comes back to another terminal of the piezoelectric transformer **101**. In this way, a discharge path is formed by the piezoelectric transformer **101**, the elongating pattern **501**, the solder land **301**, the reference potential pattern **302**, and the solder jet flow **401**. Accordingly, the dis-

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charge current does not flow into the semiconductor component **119**. The reference potential pattern **302** that gives a reference potential to the piezoelectric transformer **101** may be a ground line or a power supply line. As described above, the elongating pattern **501** that is elongated from the terminal land of the piezoelectric transformer **101** to a connected component is located parallel to the semiconductor component **119** in the travelling direction of the printed circuit board **210**. In addition, the reference potential pattern **302** is located between the elongate pattern **501** and the semiconductor component **119**. This enables the semiconductor component **119** to be protected from the discharge of the piezoelectric transformer **101**. That is, the fourth embodiment attains similar effects to those in the first and second embodiments.

While the present embodiment has been described using a model that generates discharge from a secondary terminal of the piezoelectric transformer **101**, the present embodiment is also effective for discharge from a primary terminal of the piezoelectric transformer **101**. Also, while the description was based on a model that generates negative discharge, the present embodiment is also applicable to a model that generates positive discharge.

FIFTH EMBODIMENT

In a fifth embodiment illustrated in FIG. 6, points that overlap with those of the fourth embodiment will not be described. A feature of the fifth embodiment is that an elongation direction of an elongating pattern **502** that extends from a terminal land of a piezoelectric transformer **101** to rectifier diodes **102** and **103**, for example, forms an angle α of more than 90 degrees ($\alpha > 90^\circ$) with the travelling direction (the direction indicated by arrow **211**). The elongating pattern **502** is located at the rear of a broken line G that is orthogonal to the travelling direction and that passes through the terminal land of the piezoelectric transformer **101**.

A reference potential pattern **302** that gives a reference potential (a ground potential in the present example) to the piezoelectric transformer **101** and a pattern for a ground terminal of a semiconductor component **119** are connected through a wiring portion of a printed circuit board **210**, so that both of the patterns have a common potential. Assume in FIG. 6 that the piezoelectric transformer **101** is immediately before reaching a solder jet flow **401** or in the course of preheating. Also assume that the semiconductor component **119** is passing through the solder jet flow **401**.

If the piezoelectric transformer **101** that is immediately before reaching the solder jet flow **401** or in the course of preheating is rapidly heated by a heater (not shown) or by the heat of the solder jet flow **401**, the pyroelectric effect causes a spark discharge **203** to be generated from a secondary terminal to the land. Since the spark discharge **203** has a negative polarity, the discharge current flows in a direction toward the piezoelectric transformer **101**. This discharge current flows through the reference potential pattern **302** for the piezoelectric transformer **101** via a yet-to-be-soldered rectifier diode **102** and comes back to a primary terminal of the piezoelectric transformer **101**. At that time, a spark discharge **205** is generated at the primary terminal of the piezoelectric transformer **101**. That is, a discharge path is formed by the secondary terminal of the piezoelectric transformer **101**, the elongating pattern **502**, the rectifier diode **102**, the reference potential pattern **302**, and the primary terminal of the piezoelectric transformer **101**. Accordingly, the discharge current does not flow into the semiconductor component **119**.

As described above, the circuit configuration of the fifth embodiment also attains a similar effect to that in the first

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embodiment. In particular, the elongating pattern **502** that is elongated from the terminal land of the piezoelectric transformer **101** is wired in such a direction as to form an angle of more than 90 degrees with the travelling direction. This suppresses the passage of discharge current into the semiconductor component **119** through the solder jet flow **401**. On a printed circuit board where multiple piezoelectric transformers and multiple semiconductor components are located in a complicated manner, the fifth embodiment is particularly effective for a terminal land of a piezoelectric transformer that is located closest to the tip of the printed circuit board in a travelling direction, and for an elongating pattern elongated therefrom. In other words, the protection effect is enhanced by adopting, as a land that forms part of a discharge path, the elongating pattern **502** that is elongated backward from one of multiple terminals of piezoelectric elements that is located closest to the tip of the printed circuit board in the travelling direction. Note that the elongating pattern **502** is a pattern that brings a piezoelectric element and either a rectifier element or a driving element into conduction. In the case where a rectifier element or a driving element is connected at one end to the elongating pattern **502** and connected at the other end to the reference potential pattern **302**, the rectifier element or the driving element also forms part of a discharge path. Since the rectifier element or the driving element has a higher electrostatic withstand voltage than the semiconductor component **119**, there is no problem if the element forms part of the discharge path. Note that the protection effect may be further enhanced by combining the fifth embodiment with any one of the first to fourth embodiments.

SIXTH EMBODIMENT

A feature of the present embodiment is that the shape and size of a terminal of a piezoelectric element are determined relative to a hole that is provided for insertion of a terminal in a printed circuit board, so that the side face of the terminal and the outer wall of the hole are brought into conduction or into intimate contact with each other.

As illustrated in FIGS. 12 and 11, if there is a gap (space) between the terminal **504A** or **504B** of the piezoelectric transformer **101** and the solder land **604** (in other words, if the terminal and the solder land are not in intimate contact with each other), a high voltage generated due to the pyroelectric effect is transmitted as a spark discharge over the gap. The discharge current associated with an aerial discharge or a spark discharge has a smaller time constant than the discharge current resulting from ordinary contact discharge, so charge travels with extremely short pulses. It is thus highly difficult to provide protection with a terminal protective diode provided at a terminal of the semiconductor component **119** or with a terminal capacitance. Also, in the case of aerial discharge, the discharge voltage also varies depending on the length of a gap. A shorter gap reduces the level of voltage that passes into a discharge destination and accordingly increases a margin for the electrostatic withstand voltage. If the protection methods that have been described in the first to fifth embodiments are employed while either restraining the generation of aerial discharge so as to generate only contact discharge or narrowing a gap between a terminal and a land so as to reduce the discharge voltage, the quality of protection will be improved greatly.

A feature of the configuration of a terminal land portion illustrated in FIGS. 7A and 7B is that a terminal **504** has a square shape in horizontal section, a terminal insertion hole **704** also has a square shape in horizontal section, and the outer wall of the terminal insertion hole **704** and the side face

of the terminal **504** form an angle, in other words, they are not parallel to each other. Referring to FIG. 7A, the outer wall of the terminal insertion hole **704** and the side face of the terminal **504** form an angle of 90 degrees. This is in order to bring an edge portion of the terminal **504** into intimate contact or contact with the outer wall of the terminal insertion hole **704**.

Moreover, such intimate contact or contact may be improved by devising the shapes and sizes of the terminal insertion hole **704** and the terminal **504**. For example, the length of the longest line segment of the terminal **504** in horizontal section may be made longer than the length of the shortest line segment of the terminal insertion hole **704** in horizontal section before the terminal **504** is inserted into the terminal insertion hole **704**. With those shapes and sizes, the terminal **504** is inserted into the terminal insertion hole **704** while scratching the outer wall of the terminal insertion hole **704** with its edge portion. This is one technique for bringing the edge portion of the terminal **504** into intimate contact or contact with the outer wall of the terminal insertion hole **704**. In this way, the gap between the edge of an exposed portion (solder land **604**) of the copper foil **602** and the terminal **504** can be eliminated or shortened.

As illustrated in FIGS. 8A and 8B, an L-shaped terminal **505** in horizontal section is adopted instead of the rectangular terminal **504**. The horizontal direction as referred to herein is a direction that is parallel to the surface of a printed circuit board **210**. Such an L-shaped configuration in cross section allows the terminal **505** to be somewhat elastic in its lateral direction. Also, with the terminal **505** inserted into the terminal insertion hole **704**, the terminal **505** elastically butts against the outer wall of the terminal insertion hole **704**. Thus, a gap between the end of an exposed portion of the copper foil **602** and the side face of the terminal **505** may be either eliminated or shortened. In particular, such an effect of shortening a gap is further enhanced with use of a metal such as a high-elastic stainless steel or phosphor bronze as a material for the terminal **505**.

A feature of a terminal land portion illustrated in FIGS. 9A and 9B is that a conductive member **901** for conduction between a terminal **504** and a terminal insertion hole **704** is provided between the terminal **504** and the terminal insertion hole **704**. The conductive member **901** is a metal, a conductive rubber, or a conductive adhesive, for example, that is provided on the wall surface of the terminal insertion hole **704**. The conductive member **901** brings the terminal **504**, the land **604**, and the copper foil **602** into conduction, thus eliminating or shortening a gap.

As described above, in the sixth embodiment, a discharge gap between a terminal and the solder land **604** may be eliminated or shortened by devising the shapes and sizes of the terminals **504** and **505** and the terminal insertion hole **704** or by adding the conductive member **901**. This results in a reduction in the voltage applied to a discharge destination, thus enhancing the effect of protecting the semiconductor component **119**. Of course, a higher protection effect will be attained if the sixth embodiment is combined with one or more of the first to fifth embodiments.

OTHER EMBODIMENTS

Finally, a method for manufacturing an electronic apparatus will be described. First, a land that is connected to a reference potential pattern **302** is formed between a semiconductor component **119** and a piezoelectric transformer **101** by exposing a wiring portion of a solder resist layer on a printed circuit board **210**. Then, the semiconductor component **119** and the piezoelectric transformer **101** are mounted on the

printed circuit board **210**. Moreover, the printed circuit board **210** with the semiconductor component **119** and the piezoelectric transformer **101** is brought into contact with a solder jet flow **401** while moving the printed circuit board **210** in a predetermined direction (the direction indicated by arrow **211**). A discharge current generated at the piezoelectric transformer **101** due to the pyroelectric effect flows through a discharge path formed by the piezoelectric transformer **101**, the land, and the reference potential pattern **302**. Accordingly, little discharge current flows into the semiconductor component **119**. Note that the solder jet flow **401** may be included in the discharge path.

While the present invention has been described with reference to exemplary embodiments, it is to be understood that the invention is not limited to the disclosed exemplary embodiments. The scope of the following claims is to be accorded the broadest interpretation so as to encompass all such modifications and equivalent structures and functions.

This application claims the benefit of Japanese Patent Application No. 2009-119073, filed May 15, 2009 which is hereby incorporated by reference herein in its entirety.

What is claimed is:

1. An electronic apparatus comprising:

a circuit board with an electronic component and a piezoelectric element, the circuit board being transported so as to solder the electronic component and the piezoelectric element to the circuit board;

a reference potential pattern that is connected to at least one of the electronic component and the piezoelectric element on the circuit board; and

a solder land connected to the reference potential pattern on the circuit board,

wherein, on the circuit board, the solder land is located between the piezoelectric element and the electronic component, and the piezoelectric element is located on an upstream side in a transport direction of the circuit board with respect to a position of the solder land.

2. The electronic apparatus according to claim 1, wherein a resist of the reference potential pattern is partly removed so as to form the solder land.

3. The electronic apparatus according to claim 1, wherein, in a soldering process for mounting the electronic component and the piezoelectric element on the circuit board, a discharge current generated at the piezoelectric element due to a pyroelectric effect is caused to pass into the solder land and a discharge path formed by the reference potential pattern.

4. The electronic apparatus according to claim 3, wherein the electronic component and the piezoelectric element are located on the circuit board so that a straight line that connects the electronic component and the piezoelectric element is approximately orthogonal to the transport direction of the circuit board.

5. The electronic apparatus according to claim 1, wherein the solder land includes a pattern that is part of the reference potential pattern and that extends in the transport direction of the circuit board.

6. The electronic apparatus according to claim 1, wherein the solder land is a kind of land that is provided around the electronic component in order to restrain solder bridging.

7. The electronic apparatus according to claim 3, further comprising an elongating pattern that is elongated from a terminal of the piezoelectric element forward in the transport direction of the circuit board and that forms part of the discharge path.

8. The electronic apparatus according to claim 1, wherein the solder land is an elongating pattern that extends backward

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from one of a plurality of terminals of the piezoelectric element that is located at the end of the circuit board in the transport direction.

9. The electronic apparatus according to claim 8, wherein the elongating pattern is a pattern that brings the piezoelectric element and either a rectifier element or a driving element into conduction.

10. The electronic apparatus according to claim 1, wherein the shape and size of a terminal of the piezoelectric element are determined relative to a hole that is provided for insertion of the terminal in the circuit board, so that a side face of the terminal and an outer wall of the hole are brought into conduction or intimate contact with each other.

11. The electronic apparatus according to claim 10, wherein the length of a longest line segment of the terminal in horizontal section is longer than the length of a shortest line segment of the hole in horizontal section before the terminal is inserted into the hole.

12. The electronic apparatus according to claim 10, wherein the terminal is L-shaped in horizontal section.

13. The electronic apparatus according to claim 10, wherein a conductive member for conduction between the terminal and the hole is provided between the terminal and the hole.

14. An electronic apparatus comprising:

a circuit board with an electronic component and a piezoelectric element;

a reference potential pattern that is connected to at least one of the electronic component and the piezoelectric element on the circuit board; and

an elongating pattern connected to the reference potential, that extends from a terminal in transport direction of the circuit board, wherein the terminal is located in the most downstream side among a plurality of terminals of the piezoelectric element while the piezoelectric element is mounted on the circuit board.

15. The electronic apparatus according to claim 14, wherein a discharge current generated at the piezoelectric element due to a pyroelectric effect during mounting of the electronic component and the piezoelectric element is caused to pass into a discharge path formed by the piezoelectric element, the elongating pattern, and the reference potential pattern.

16. A high-voltage power supply that is installable on an image forming apparatus, comprising:

a circuit board with an electronic component and a piezoelectric element, the circuit board being transported so as to solder the electronic component and the piezoelectric element to the circuit board;

a reference potential pattern that is connected to at least one of the electronic component and the piezoelectric element on the circuit board; and

a solder land connected to the reference potential pattern on the circuit board,

wherein, on the circuit board, the solder land is located between the piezoelectric element and the electronic component, and the piezoelectric element is located on an upstream side in a transport direction of the circuit board with respect to a position of the solder land, and a high voltage that is output from the piezoelectric element is applied to a process member of the image forming apparatus.

17. A printed circuit board including an electronic component and a piezoelectric element, the printed circuit board being transported so as to solder the electronic component and the piezoelectric element to the circuit board, the printed circuit board comprising:

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a reference potential pattern that is connected to at least one of the electronic component and the piezoelectric element on a circuit board; and

a solder land connected to the reference potential pattern on the circuit board,

wherein, on the circuit board, the solder land is located between the piezoelectric element and the electronic component, and the piezoelectric element is located on an upstream side in a transport direction of the circuit board with respect to a position of the solder land.

18. The printed circuit board according to claim 17, wherein a discharge current generated at the piezoelectric element due to a pyroelectric effect of the piezoelectric element being caused to pass into a discharge path formed by the solder land and the reference potential pattern.

19. A printed circuit board comprising:

an electronic component;

a piezoelectric element;

a reference potential pattern that is connected to at least one of the electronic component and the piezoelectric element; and

an elongating pattern connected to the reference potential pattern, that extends from a terminal in a transport direction of the circuit board, wherein the terminal is located on the most downstream side among a plurality of terminals of the piezoelectric element while the piezoelectric element is mounted on the circuit board.

20. The printed circuit board according to claim 19, wherein a discharge current generated at the piezoelectric element due to a pyroelectric effect during mounting of the electronic component and the piezoelectric element is caused to pass into a discharge path formed by the piezoelectric element, the elongating pattern, and the reference potential pattern.

21. The electronic apparatus according to claim 1, wherein the electronic component is located on a downstream side in the transport direction of the circuit board with respect to the position of the solder land.

22. The electronic apparatus according to claim 14, further comprising other solder land located between the electronic component and the piezoelectric element.

23. The power supply according to claim 16, wherein the electronic component is located on a downstream side in the transport direction of the circuit board with respect to the position of the solder land.

24. The power supply according to claim 16, wherein the process member comprises a transfer roller for transferring an image on a sheet.

25. The printed circuit board according to claim 17, wherein the electronic component is located on a downstream side in the transport direction of the circuit board with respect to the position of the solder land.

26. The printed circuit board according to claim 19, further comprising other solder land located between the electronic component and the piezoelectric element.

27. A electronic apparatus comprising:

a circuit board with an electronic component and a piezoelectric element;

a reference potential pattern that is connected to at least one of the electronic component and the piezoelectric element on the circuit board; and

a solder land connected to the reference potential pattern on the circuit board,

wherein the solder land is located between the electronic component and the piezoelectric element.

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- 28.** A printed circuit board comprising:
 an electronic component;
 a piezoelectric element;
 a reference potential pattern that is connected to at least one
 of the electronic component and the piezoelectric ele- 5
 ment on the circuit board; and
 a solder land connected to the reference potential pattern
 on the circuit board,
 wherein the solder land is located between the electronic
 component and the piezoelectric element. 10
- 29.** A high-voltage power supply that is installable on an
 image forming apparatus, comprising:
 a circuit board with an electronic component and a piezo-
 electric element;
 a reference potential pattern that is connected to at least one 15
 of the electronic component and the piezoelectric ele-
 ment on the circuit board; and
 a solder land connected to the reference potential pattern
 on the circuit board,
 wherein the solder land is located between the electronic 20
 component and the piezoelectric element.

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- 30.** A method of soldering an electronic component and a
 piezoelectric element on a printed circuit board, the method
 comprising the steps of
 mounting the electronic component and the piezoelectric
 element on the printed circuit board having a reference
 potential pattern and a solder land connected to the ref-
 erence potential pattern, such that the solder land is
 located between the electronic component and the
 piezoelectric element, and
 soldering the electronic component and the piezoelectric
 element on the printed circuit board by transporting to a
 solder jet flow the printed circuit board on which the
 electronic component and the piezoelectric element is
 mounted.
- 31.** The method according to claim **30**, further comprising
 the step of mounting the electronic component on the printed
 circuit board on a downstream side in a transport direction of
 the printed circuit board with respect to a mount position of
 the solder land.

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